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CHINESE RESEARCH AND DEVELOPMENT OF FERRO-BASE HIGH TEMPERATURE ALLOY GH 140

Huang Fu Xiang

In aviation engines, the flame tubes of the combustion chambers are an important hot junction component. Because of the fact that the walls of these flame tubes are always existing under very high operating temperatures, their distributions are very uneven, and in operation, they often give rise to periodic changes; the result of these changes is to lead to very large thermal stresses and these stresses cause the flame tube to give rise to cracks and twisting deformations. In order to satisfy the utilization requirements for the components of the combustion chambers, in countries outside China, it was general practice to make a great deal of use of high temperature nickel alloys strengthened by solid solutions in order to manufacture these types of components. These alloys all had excellent characteristics in the areas of resistance to oxidation, high plasticity, definite thermal strengths and good working characteristics in such areas as thermal fatigue characteristics and blast pressure characteristics as well as welding capabilities. Our country is a developing nation and in order to save on the expense of the precious element nickel, at the same time that we were developing high temperature nickel alloys, we put 20 years of research into another idea and developed a series of ferro-based high temperature alloys to be used in the manufacture of parts for the combustion chambers of engines for aircraft, the operating temperatures of which would be 950°C or lower. GH140 alloy is nothing else but one type from this series of alloys, a type which has been relatively successful and which can be applied in the widest range of uses of all the alloys in the series. This alloy makes use of a solid solution strengthening process and is capable of satisfying the utilization requirements involved in manufacturing parts for combustion chambers; it can also be used in the manufacture of aviation engines with operating temperatures at

or under 850°C as well as in the manufacture of parts for combustion chambers in afterburners or thrust augmentation systems. This alloy is already in production and use and has undergone a long period of testing under conditions of actual application; the results have been excellent and the use of this alloy has saved large amounts of the element nickel for our country. Besides this, because of the fact that the working characteristics of this alloy are so very good, that it is reliable when it is used, and that it is inexpensive, it has been welcomed by various factories involved in production for aviation and it has been steadily gaining wide acceptance in the field of production for the sorts of turbine jet engines which are used in civil aviation. At present, GH140 alloy has already become one of the widely used high temperature alloys employed in the aviation industry of China. The important types of this alloy which are produced are in the forms of cold-rolled thin plates and hot-rolled intermediate plates; besides this, there are other forms of the alloy such as wire materials, rods, forged goods, hot-rolled tubing as well as cold-drawn tubing and so on.

A SIMPLE INTRODUCTION TO ALLOYS

The base for these alloys is a solid solution of Fe-37Ni-20Cr which uses the elements 2W, 2Mo, Al, Ti and so on to carry out a complete strengthening with the Austenite bodies. A high chromium content maintains the alloy in possession of excellent capabilities as far as resistance to oxidation and resistance to corrosion go. A high nickel content maintains the Austenite base with an adequate stability, (this type of composition causes the alloy, when it is put through the process of solid solution, to maintain its single phase Austenite structure (Figure 1)); moreover, this composition also gives the alloy excellent overall characteristics. The production of this type of alloy can be done by making use of electric arc furnaces, electric arc + electroslag or vacuum automatic rake techniques and so on in order to carry out the metallurgical

processes required. The Al and Ti contents of the alloy have extremely large influences of the mechanical capabilities of these high temperature alloys. In order to insure that the alloys will be possessed of an excellent combination of strength and flexibility or plasticity, whenever the various metallurgical processes involved are carried out, it is necessary to exercise strict control over the contents of Al and Ti.

The mechanical characteristics of the various kinds of semi-finished goods in which these alloys come are set out in Table 1. The physical characteristics of the alloys are set out in Table 2. The specific gravity of this sort of alloy is 8.09 and that is small when compared to alloys based on nickel. The characteristics of this sort of ferro-based alloy in the area of resistance to oxidation are excellent and they are similar to those of the nickel based alloy EI602. During long term operation at temperatures of 800°C or less, it is generally not required to make use of protective measures (see Figure 2). This sort of ferro-based alloy has excellent characteristics in the area of blast pressure techniques and it is possible to use this type of alloy in the manufacture of various forms or types of complex deep blast parts or components. The capabilities of this sort of ferro-based alloy as far as welding goes are excellent; they can be used with argon arc welding, spot welding, seam welding as well as methods as solder welding and so on in order to make connections between different pieces of the material.

MECHANICAL PROPERTIES

The tensile properties of cold-rolled thin plates of this sort of ferro-based alloy (thickness 1.5 mm) under different types of temperature conditions can be seen in Figure 3. The tensile strength of this sort of alloy drops relatively little in temperature conditions under 600°C; it is only about 600°C that one begins to see drops in this sort of capability of a relatively large scale; however, even right up to 800°C, it is still possible to

maintain a certain strength level. As far as yielding strength goes, when one is dealing with a temperature level of 700°C, the fluctuations are relatively large; as far as the characteristic is concerned, it is important to maintain very careful control of the amounts of Al and Ti which are put into the alloy; when the contents of these two elements are high, then the yielding strength of the alloy will also be relatively high. These sorts of ferro-based alloys, throughout all the temperature ranges which were used during the course of the testing of these alloys, always had very high plasticity levels. Below 700°C, one would sometimes see the occurrence of areas of low plasticity; this phenomenon is related to the metallurgical processes involved and the composition of the alloy. Hot-rolled medium plates, in temperature environments of 800°C and more, were possessed of quite high strength levels.

Figure 1. The structural form of the solid solution alloy GH140. In the austenite base, there is an even distribution of Ti(CN) granules. 10% oxalic acid dialectric corrosion, 800x

When one was testing thin plates of the ferro-based alloy with a thickness of 1.5 mm, then the number of times such plates could be bent back and forth before they broke was 21-24 times; the blast depth in the experiments or tests which were carried out was 11.0-11.4 mm and this helps explain the fact that this sort of ferro-based alloy has excellent working plasticity at room temperature.

THE LONG TERM OR ENDURANCE STRENGTH OF THIS ALLOY,

From the Larson-Miller curve in Figure 4, one can see that, in temperature conditions of 700°C or less, the long term or endurance strength of this sort of ferro-based alloy is somewhat higher than that of the Soviet nickel alloy EI602 . , and that, when the

TABLE 1. The mechanical characteristics of the various forms of semi-finished goods which are made from GH140 alloy (the results presented below are minimum values)

type of goods	type of form	20 °C			800 °C		
		σ_b kg/mm^2	δ_a %	ψ %	σ_b kg/mm^2	δ_a %	ψ %
cold-rolled thin plate	1050~1080° air cooled	65	40	-	23	40	-
hot-rolled medium plate	1050~1080° air cooled	65	40	45	25	40	50
rods	1080±10°C air cooled	63	40	45	25	40	50

temperature conditions are 800°C or more, then the characteristics of the two types of alloys are basically the same. The curve for high temperature fatigue in plate-type examples of GH140 ferro-based alloy can be seen in Figure 5; in this figure one can see that when the temperature of the alloy is 700°C, the fatigue strength is 32 kg/mm^2; one can also see that when the temperature of the alloy is 800°C, then the fatigue strength is 16 kg/mm^2. The results of experimentation in the area of thermal fatigue also shows us that the thermal fatigue characteristics of GH140 alloy are quite comparable to those of EI602 alloy. The overall dynamic characteristics of these ferro-based alloys are completely capable of satisfying the requirements for use in the manufacture of components for flame tubes.

HEAT TREATMENT AND METAL PHASE STRUCTURE

When one is considering the case of plate-type materials, then in temperature ranges of 1000-2000° C, after treatment with solid solutions is accomplished, all of these types of materials are capable of achieving a unified Austenite structure. However, following along with any increase in the temperature of the solid solution, goes an elongation of the Austenite crystals; concurrent with this one finds that, when the long-term or endurance strength of this type of ferro-based alloy as well as its creep strength go up, then their instantaneous, high temperature strength goes up

as well, and the fatigue strength and the high temperature plasticity of this type of alloy go down. In order to achieve excellent overall characteristics when one makes use of GH140 plate-type materials in the manufacture of parts for flame tubes, it is possible, at 1080°C, to carry out a final tempering; given this, at the time when the blast pressure forms the parts, a concurrent heat

TABLE 2. The physical characteristics of GH140 alloy

Temperature °C	Modulus of elasticity kg/mm^2	coefficient of linear expansion mm/m·°C (20°C-T°C)	Coefficient of electrical resistance Ohms·mm^2/m	coefficient of thermal conductivity in calories/cm · sec·°C
20	19800	-	-	1.07
100	19350	12.7×10^{-6}	0.036	
200	18750	13.8×10^{-6}	0.040	
300	18300	14.3×10^{-6}	0.043	
400	17700	14.6×10^{-6}	0.046	
500	16900	15.1×10^{-6}	0.050	
600	16300	15.4×10^{-6}	0.053	
700	15400	15.8×10^{-6}	0.056	
800	14750	16.3×10^{-6}	0.060	
900	14000	16.7×10^{-6}	0.063	
1000	13000	17.5×10^{-6}	—	

treatment can be carried out at 1050°C. At this time, it is possible to completely eliminate all the hardness of the material as it has been worked and it becomes possible to achieve a crystalline structure of uniform fineness. In the case of components for afterburners or thrust augmentation systems and their combustion chambers, the appropriate temperature at which to carry out the same sort of tempering procedure is 1150°C; at such a temperature, it is possible to achieve the greatest long-term strength as well as the greatest creep strength.

The type of alloy which we have been discussing, after it undergoes the solid solution treatment, and undergoes long term

use in a temperature range of 550-900°C, is capable of producing a decomposition of the solution of the solids, giving rise to such component phases as $Cr_{23}C_6$, γ', σ and Laves. If we take the case in which the alloy has been exposed to the long term effects of 700°C temperatures, then the amount of decomposition is relatively large with an overall amount of approximately 8%; see Figure 6. $Cr_{23}C_6$ is a principal crystalline boundary strengthening phase; its decomposition or "splitting off" temperature range is 550-900°C; when the temperature is relatively low, it takes the form of a thin chain; with increases in the aging temperature, this shape becomes gradually elongated; moreover, it becomes gathered together until it assumes a globular shape (Figure 7a-c). In the analysis of the

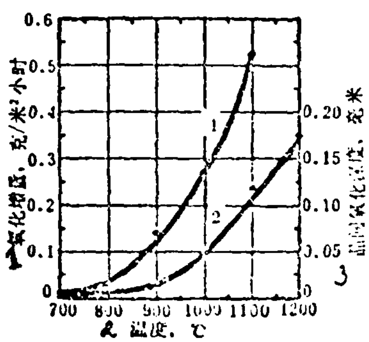


Figure 2. The increase in weight due to oxidation (1) and the depth of oxidation between crystals (2) after 100 hrs of testing of GH140 alloy in a high temperature environment of static air.

1) amount of oxidation by weight in grams/m² hrs; 2) temperature; 3) depth of oxidation between crystals in mm

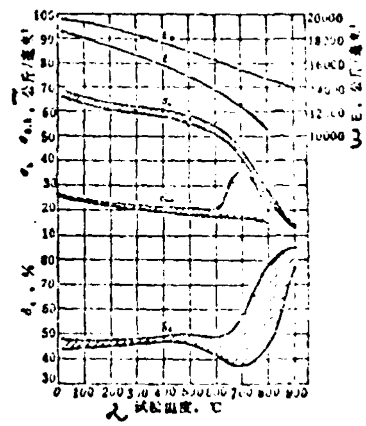


Figure 3. The tensile characteristics of GH140 alloy in the form of cold rolled thin plates in the form of a solution of solids (temperature maintained at 1080°C for 10 sec, air cooling).

1) kg/mm²; 2) experimental temperature; 3) kg/mm²

aging process, the γ' phase is an important strengthening phase; it presents the appearance of small globular-shaped points of matter (Figure 7a); the temperature at which it makes its appearance is in the range of 550-8[illegible]0°C; one can say that the amount of these globules is greatest at 700°C and that the size of the γ' points as well as their number and stability are determined by the content of Al and Ti in the alloy and particularly by the distribution of them in the crystals.

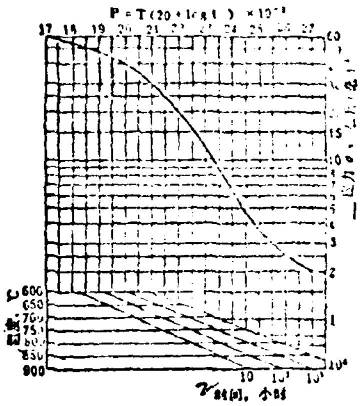


Figure 4. The long term strength of GH140 alloy in the form of thin plates as shown by Larson-Miler curves (1080°C solid solution treatment). T is the temperature for the tests (°K). t is the long term life of the alloy in hours.

1) temperature; 2) time in hrs; 3) stress in kg/mm²

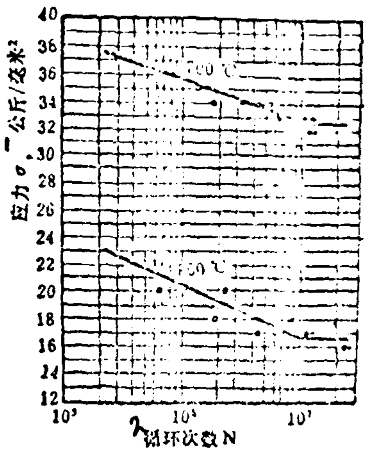


Figure 5. Fatigue curves for plate-type materials made from GH140 alloy and exposed to high temperatures (1080°C solid solution treatment)

1) stress in kg/mm²; 2) cycle number

σ and Laves phases are two types of flawed phases which occur with aging at 700-800°C; their occurrence is particularly found distributed in the crystals; they can present the form of needles or sticks as well as that of globular pieces of matter (Figure 7b-c); in the aging process, these objects are very rapidly lengthened and are capable of lowering the strength and the plasticity of the alloy involved. The Laves phase (Fe_2Mo form) appears at 700°C and

the σ phase (FeCr form) appear at the same time and temperature; we may take the σ phase as the primary one since the Laves phase is very rare. At 800°C only the σ phase appears and most of the time it reaches a concentration of 4% of the alloy. To summarize everything, due to the fact that the degree of amalgamation of the elements which go together to form GH140 alloy is relatively low, in the process of long term aging at high temperatures, the number of second phase occurrences is relatively small; because of this fact, there are definite limitations imposed on the influence which these occurrences of secondary phases can have on the capabilities of the alloy. For example, when the alloy is subjected to long term aging for 2000 hours at 700-800°C, the rate of elongation at room temperature drops a maximum of 17%; it can be seen that the effects of long term aging in terms of changes in the high-temperature capabilities of the alloy are relatively small.

BASIC FACTS CONCERNING APPLICATIONS

GH140 alloy was primarily developed to be used for the manufacture of parts in combustion chambers. This type of alloy has seen use as a replacement for nickel-base alloys in the manufacture of several types of turbine jet engine combustion chamber flame tubes (see Figure 8); moreover, long-term application tests have been carried out on this type of alloy and the results have been excellent. After the GH140 alloy has been used in the flame tubes, the incidence of malfunctions has been similar to that which was the case with the nickel-based alloys. Of the parts which are manufactured out of this type of alloy, the main ones also include afterburner or thrust augmentation diffusion devices, the bodies of afterburner or thrust augmentation tubes, transfer rings for afterburners or thrust augmentation devices, and the skin of the aircraft as well as other similar components. The life of the flame tubes, depending on the conditions under which they are used, can be very different and show very marked variations; for example, in some turbine jet engines, due to the fact that the number of times which the engines were started up was relatively great and

there were frequent changes in the operating modes of the engines as well as the fact that the time which the engines were allowed to run each time they were started up was relatively short, once the flame tubes were used, they saw the occurrence of frequent malfunctions and their lives were relatively short--in general, a few hundred hours. On the other hand, when one is considering turbine blades and the turbines themselves in engines which are allowed to run relatively long times once they are started up and, in which the changes in the operating modes were relatively small and infrequent, then malfunctions of the flame tubes are relatively few and the useful life of the flame tubes is generally several thousand hours. As was also the case with alloys based on nickel, alloys which are based on iron make flame tubes which, during their use, frequently give rise to malfunctions and suffer from the problems of burning, distortions and cracking as well as other related problems. There is a very close relationship between the appearance of these sorts of malfunctions and the structure and conditions of use of the flame tubes involved; the most important among these factors are the operating temperature of the walls of the flame tubes involved as well as the number of temperature or ciculatory cycles. Actual application of the type of ferro-based alloy about which we have been talking demonstrates that when flame tubes are possessed of excellent design structures, then this guarantees the prerequisites which are necessary for the reliable operation of the materials used in those flame tubes.

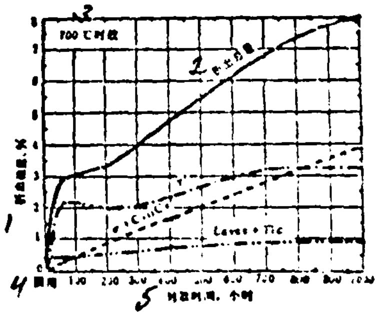


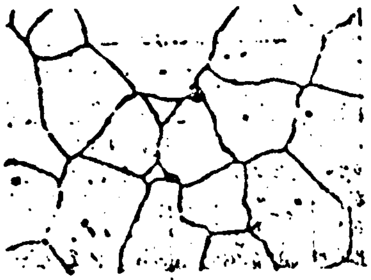
Figure 6. Changes in the number of phases which appear in GH140 alloy during the process of its aging over extended period in 700°C temperatures

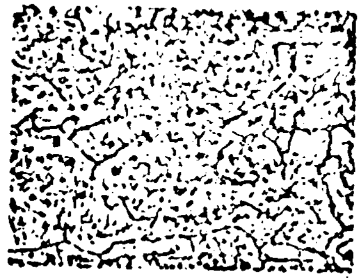
1) percentage of appearance of secondary phases; 2) overall amount of appearance; 3) aging; 4) solid (one character illegible); 5) aging time in hrs.

A structural capability analysis was done on samples taken from ring combustion chamber flame tubes of turbofan engines which had undergone 2000 hours of extended use (Figure 8d). On the basis of the finding that the maximum operational temperature for this type of flame tube was 780°C and the fact that most of the components had operating temperatures between 500 and 700°C, the flame tubes which had gone through extended operation still did not show the appearance of major malfunctions. The various sections of the flame tubes we have been talking about, based on the different operating temperatures for each of them, have the different phases of $Cr_{23}C_6$, γ', σ and Laves. The mechanical characteristics of the various sections also undergo changes to differing degrees; to generalize, the high temperature instantaneous tensile strength and long-term strength for the various sections of the flame tubes are both increased and some undergo relatively large increases; on the other hand, the plasticity of the various sections experiences something of a decline and the rate of expansion or stretch is at least 15%. In the vicinity of gas film holes, the heat fatigue characteristics of the materials which we have been discussing are still found to be maintaining the levels of the original materials. This takes one more step toward demonstrating that, when the operating temperatures are 800°C or less, GH140 alloy is capable of extending a reliable use in the operation of the combustion chamber components about which we have been talking; the turbofan-type flame tubes which were discussed above, after going through 2000 hours of use, were still capable of continuous, long term operation even further into the future.

If one makes a comparison between GH140 alloy and the nickel base alloys which it replaced, one finds that there are the following weaknesses associated with it; 1) the high temperature resistance of the ferro-base alloy to oxidation was somewhat inadequate, and in extended use at high temperatures (such as temperatures higher than 900°C), it was easy to get the appearance of burning malfunctions; 2) the fatigue strength of the ferro-based alloy was somewhat low in the medium range of operating temperatures (500-600°C)

Figure 7. Structure of GH140 alloy after long term aging of various temperatures.

a) 

b) 

a. Condition, 550°Cx1000 hours aging, structure: grain boundaries $Cr_{33}C_6$+Ti(CN). 800x

b. Condition, 700°Cx1000 hours aging, structure: grain boundaries $Cr_{33}C_6$, inside the grain σ, Laves, Ti(CN). 800x

c) 

d) 

c. Condition, 800°Cx700 hours aging, structure: $Cr_{33}C_6$, σ. 800x

d. Condition, 700°Cx1000 hours aging, structure: γ' 35000X

and this resulted in the rate of failures due to fatigue which were produced in components with certain definite types of structure forms and operating in the medium range of operational temperatures being somewhat higher than the corresponding rate for the alloys which were based on nickel; 3) in the case of the ferro-based alloy, the structural stability which was found during extended use at high temperatures was somewhat inadequate, and it was easy for changes to take place in the capabilities of this type of material. The weak points of this type of ferro-based alloy, as they have been discussed above, can be overcome in certain ways during the actual application of the alloys; moreover, it will be possible hereafter to continuously improve on these weaknesses during the process of research into and actual application of these types of ferro-based

alloys.

Figure 8. Several types of combustion chamber flame tubes from aviation engines. These are manufactured using GH140 alloy.

a. single tube type; b. ring type; c. tube ring type

Introduction to a factory which specializes in the production of precision cast components

HOWMET TURBINE COMPONENTS CORPORATION

[Throughout this document the Hau Mei Te Company=Howmet Turbine Components Corporation in Muskegon, Michigan.]

Hua Rui-xi

The Howmet Turbine Components Corp. is the largest precision cast component company in North America; it specializes in the production of precision cast components which are used in hot junctions of turbine engines and it supplies various companies which are major producers of aviation engines and gas turbines as well as subsidiaries in Europe.

According to statistics, this company produces products 36% of which are used in engines for civil aviation, 24% of which are used in aircraft engines for military use, 20% of which are used in engines for use on land, 5% of which are used in the aerospace industry and the rest of which are used by industry in general. As far as the products of this company are concerned in the area of precision cast components, it can be said that they are used in most of the civil and military aviation engines in the world. At present, several types of aircraft engines which the U. S. is currently using all make use of the precision cast components made by this company. For example, the engine called CF6-50 makes use of 16 types of 855 components; the JT9D engine makes use of 15 types of 1434 components; and, the F100 engine makes use of 25 types of 454 components. In the last 10 years, the amount of sales for this company have increased without a break every year; in 1976, its sales reached 200 million U. S. dollars.

This company, beginning in January of 1976, became a subsidiary or branch company of larger firms; this move obtained for them stronger technological and financial support. However, this company still has its own management as well as executive staff, accountants, auditors and so on. The employees of this company

number approximately 5000 people. The home office of the company is located in Muskegon, Michigan; the five coordinate offices or sections which are set up under this headquarters are as follows: single-shell or single-piece cast component section, the international industries section, the alloys section, the product service section, and the active metals section. Besides this, there is also a technology center which provides technological support to each of the various other sections. This company is not only capable of providing precision cast components, it is also capable of providing products in the form of spare parts which can be mounted straight unto an engine. The active metals section is capable of producing titanium ingots and pure titanium cast components as well as sponge-type titanium. Each of the sections about which we have talked can be further divided into several sub-divisions.

All together, the whole company has 15 of these sub-divisions. Each of these sub-divisions independently and individually undertakes the responsibility for the accounting of its production costs and profits as well as for its engineering development and its sales. The personnel responsible for each of the sub-divisions possess quite a large amount of freedom of action to carry out the development of their various enterprises.

Now we will take this company in terms of its various offices or sections and sub -sections and give a simple introduction to them as follows.

One. Single piece casting section. This is the main section or office of this company and it is divided into four sub-sections which take on the responsibility for the important tasks associated with production. The alloys section and the product service section as well as other sections of a similar type all coordinate the development of their activities with the single piece casting section. The active metals section produces titanium alloy cast components and cast ingots.

1. The ADD division is located in New Jersey and produces mainly precision cast components of the blades in aviation engines which are used in civilian and military applications. Among these products there are many which are air cooled blades made of nickel base and cobalt base high quality alloys. The products of this section make use of ceramic form cores which are made by the company itself in order to form tne fine internal cavity passageways in the blades and other similar products. One of the specialities of this section is the production of directional crystal cast components. Turbine blades which employ directional crystals are capable of eliminating horizontal crystal boundaries along the intake edges of the blades; by doing this, it is possible to raise the high temperature strength of the blades. This technology was first developed by other American companies. However, the Hau Mei Te Company, by acquiring the license for production, has already become the principal firm which supplies directional crystal cast components. This company is, at present, in the midst of developing the technology for the economically practical production of high quality single-crystal and eutectic crystal alloys.

2. The ALD branch is located in Laporte, Indiana. This section is especially involved in the development of the technology for the large scale production of complete precision cast components; these sorts of components are principally used in small-scale turbine engines. This section did the complete casting of the compressor stators which involved eight stages and were used in the test manufacture of the F-100 engine. This section discovered the pattern, made from a mixture of plastic and wax, which is capable of causing an increase in the precision of cast components as well as in the smoothness of the surfaces of those components. This section also produces a lot of vane wheels for pressurization in diesel engines and its sales are undergoing a rapid increase. It also produces structural components for small engines such as components for the combustion chambers of afterburners, turbine and compressor casings as well as axial bearings and other components of a similar kind.

3. The MHD section is located in Hamilton, Virginia and specializes in the production of large-scale cast components for use in gas turbine engines for use on land. Its technology and equipment are all set up according to the requirements for the making of large-scale cast components. The key production organization of this section has been automated, has been equipped with a large-scale machine for the addition of wax as well as with a mechanized production line for the manufacture of casting molds, a one million volt piece of X-ray equipment and other related types of equipment. This section has developed techniques for increasing the degree of precision in the dimensions of products and these techniques make it unnecessary to make corrections to the cast components which makes it possible to reduce the residual stresses involved. The largest vacuum cast components which this section is capable of producing can reach 91 kg and those components which are cast in the open air can reach, as a maximum, 136 kg.

4. The MWD section is located in Michigan and is the largest section of the Hau Mei Te Company. This section specializes in the manufacture of the cast components for blades used in aviation engines which are employed in both civilian and military applications. Among these components, the majority are complex and have high precision air cooling passageways in them. The primary responsibility for the selection of the most profitable techniques for the manufacture of one-piece castings lies with this section. Isothermal static pressure techniques are also one of the areas in which this section is involved. These types of technical production methods are capable of causing cast components to achieve their maximum possible reliability levels while, at the same time, adding as little as possible to the expenses involved. This section also has facilities for the manufacture of directional crystal components. The production costs for the manufacture of directional crystal components usually turn out to be 20-50% higher than those for ordinary cast components; at present, the market requirements

for this new type of component are not as high as they were originally forecast to be and, as a result of this, this company has taken its facilities for the manufacture of directional crystals and put them into reserve, so to speak, while it relies mainly on another section of the company to be the supplier of directional crystal components.

Two. Product Service Section. This section is organized from three sub-sections, that is, the Product Processing Sub-section, the Recoating Section, and the Ceramic Products Section; all of these sections are located in Michigan.

1. The Product Processing Sub-section. The Hau Mei Te Company, several years ago, began working on the idea that the users of their products could supply them with engine components which had already been through the basic manufacturing process. At present, this sub-section of the company does remanufacturing work on 150 types of already finished and reusable components for 15 plants which manufacture turbine engines. This sub-section is equippped with various types of machine tools and lathes. One type of equipment which is particularly worthy of note is the revolving precision polishing lathe and the electrical discharge working lathe. These two types of equipment are both used to work the blade crowns of the turbine blades of engines as well as the blades of the guide vane devices of these engines. This reworking takes the form of operations performed on the interior and exterior surfaces of these blades as well as work done on the small cooling apertures in the blades. This sub-seciton is also capable of ion-spray plating onto certain localized surface areas of complex, high quality metallic structures an abrasion resistant layer; this sub-section also provides such services as gas protected, tungsten electrode arc welding, vacuum soldering and welding, and so on. At the present time, the process of working on the high quality metals in sensors already makes widespread use of low stress friction "peeling". This technique was first developed in no other place than this sub-section of the Hau Mei Te Company. This sub-section is also equipped

with the latest what is necessary to carry out procedures for testing measurement determination of the causes of damage and wear in components without having to harm those components. By means of this equipment, this sub-section can carry out effective control measures over all aspects of the products with which it works.

2. The recoating section. Each year, this section handles 300,000 pieces of company product. The Hau Mei Te Company has developed a series of protective coating layers as well as working techniques which have allowed the company to reap particular benefits; these techniques include the recoating of electrodes, diffusion coating layers in hydrogen gas, the recoating of precious metals as well as the newest types of multiple coatings and so on. This section is capable of recoating the crowns of turbine blades with hard materials; moreover, it can undertake the job of overhauling old turbine blades and it is also capable of selecting for the user the ideal coating layer to be used in a given case as well as the sequence of the heat treatment required.

3. The Ceramic Products section. This section specializes in the manufacture of the ceramic core forms which are used in the formation of the cavities inside the blades of turbines. These core forms are inserted into the wax forms. After the casting of the components is completed, use is made of the chemical corrosion method in order to get rid of the cores. Another of the activities of this section is the manufacture, for the Hau Mei Te Company and others engaged in the business of precision cast components, of crucibles manufactured from granular zirconium. This type of crucible is capable of lessening the chances of metals being polluted during the casting process; moreover, crucibles made of this sort of material have relatively longer lives than others. This section is still not equipped with facilities for the rejuvenation of the materials used in the form shells used for the casting process; this type of capability makes it possible to reuse 50% of the material from the casting forms which are used by the entire one-

piece casting section. This sort of reuse would not only obviously lower production costs, but it would also be capable of reducing the dependence of this company on materials purchased elsewhere.

Three. Alloy Section. The Alloy Section is organized from the parent alloy sub-section, the metallic products sub-section, and the crucible steel cast component section.

1. The parent alloy section. This sub-section is located in New Jersey. The principal task of this section is to produce and supply the high quality alloys based on nickel and cobalt which are smelted by induction in a vacuum and are used in precision casting activities. This sub-section is also capable, based on the requirements of the user, of producing cast ingots which are smelted by induction in air. After the alloys are smelted, whether it be in air or in a vacuum, they are then made into bar-type materials after which the bars are again transformed into bullet-shaped materials. Some high quality alloy material which is smelted in a vacuum is also capable of being made into the form of a powder in order to satisfy special requirements.

This sub-section is equipped with various types of vacuum inducing furnances and the volume of the largest of these reaches five-and-a-half tons. The sub-section is also equipped with photoelectric direct display photospectrascopes and other similar modern analytical test equipment.

2. The metallic product sub-section. This sub-section is located in Michigan and produces pellet-type or ingot-type raw alloy material for resmelting for use in supplying most of the products which are smelted in air by this company and also to supply the needs of other companies. This company also produces high temperature corrosion resistant sand form cast alloy components and hardened layer welding rods.

This sub-section of the company has four induction furnaces with a total yearly production capability of 6000 tons. This sub-section produces welding rods which are manufactured inside glass tubes by special types of production methods and these are capable of maintaining excellent surface quality and cleanness. The facility which allows the continuous casting of welding rods began production in late 1977 and is capable of producing 3.6m welding rods.

3. The crucible steel cast component sub-section. This sub-section is located in Milwaukee, Wisconsin, and produces carbon steel and low alloy, high strength steel cast components which are used in industry in general; these components consist of such things as axial bearings, large-scale valves and other similar components. This sub-section also produces cast components from stainless steel. This sub-section is equipped with two direct electric arc furnaces with a capacity of seven tons. Each month, this facility is capable of producing 2000 tons of components ranging from 0.2 kg parts to 6.8 ton components. This sub-section is also equipped with full no loss flaw detection equipment which includes supersonic test equipment, magnetic test equipment and X-ray test equipment. This sub-section also has a vacuum photo-spectrascope for analytical purposes.

Four. The Active Metals Section. This section is organized out of the Titanium Ingot Sub-section, the Titanium Casting Section and the Honeycomb Titanium Section. All of these sections are located in Michigan.

1. The Titanium ingot sub-section. This section makes pure titanium alloy ingots for commercial uses. The diameter of the standard ingot is 680-910 mm and the standard weight is 4.5-6.3 tons. The diameters of the largest cast ingots produced reached up to one meter, and the weights of these ingots reach up to 10 tons. This sub-section is equipped with one non-consumable electrode eldctric furnace and two consumable electrode electric

furnaces. Besides titanium ingots, this sub-section also supplies the resmelting electrode material for the titanium casting section of this company.

2. The Titanium Casting section. The precision casting technology of the Hau Mei Te Company has already been used in the casting of titanium alloy parts. The surface cleanness of these parts as well as their mechanical characteristics can both be considered superior to those of forged titanium components. The precision of the dimensions of cast titanium parts only requires the application of a very small amount of mechanical working.

Due to the high level of activity of titanium alloys, these alloys (continued page 11).

NEWSBRIEF

A look at the second generation of supersonic passenger planes. A recently released U. S. Congressional report discussed the question of the second generation supersonic passenger planes and the main thrust of its contents is outlined below.

The second generation of supersonic passenger planes can carry more passengers than can the Concorde generation of passenger planes. The new generation flies faster and by the year 2010, will reach a total number of 400 planes (at a cost of 50 billion U. S. dollars) and these new planes will be able to replace 800 subsonic passenger planes.

The production of this type of aircraft will be decided by the future price and supply of fuel, the requirement for long distance travel, the solution of several technological questions (such as the reduction of noise, and so on) and the availability of funds for experimental production.

Although the initial production of supersonic passenger planes will be able to supply relatively large amounts of business (this is speaking relative to new forms of subsonic passenger planes) because of the fuel consumption of these new supersonic planes, it is not certain whether they would be worth while going through with. It is estimated that the fuel consumption of the supersonic passenger planes will be 50-100% larger than that of subsonic aircraft for each mile of flight per passenger. This is simply to say that the price of a ticket on one of the supersonic passenger planes could be 20-30% higher than the cost of a first class ticket on a subsonic plane.

The amount of capital which will be needed in order to make test productions of the second generation supersonic passenger planes will be in the neighborhood of 6-10 billion U. S. dollars. This greatly exceeds the largest possible capabilities of even the largest U. S. aviation companies to undertake. One possible way of solving this problem would be for several of the large U. S. companies to go in together on the project of test production or to look to international financing.

The U. S. plans to strengthen the military reserve capabilities of its civil aviation fleet. The U. S. Congress has already appropriated more than 50 million U. S. dollars for use in strengthening the military reserve capabilities of the U. S. civil aviation fleet. In fiscal 1981, it can be expected that another 70 million dollars will be appropriated for the same purpose. The U. S. Defense Department has already put out information to 20 civilian aviation companies about the coming changes.

The funds which have been appropriated will be used to strengthen the floors of passenger planes and equip them with cargo doors so that these planes may carry passengers normally during peace time but, under emergency conditions or during war time, they may be capable of carrying troops and equipment. The work of changing the equipment and capabilities of the aircraft is in the stage of

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being carried out while the planes are on the production line. The U. S. government has given this amount of money then, during the next 16 years, during any time of emergency, the government would be allowed to use the aircraft. Because of the fact that this sort of change in the equipment of the aircraft involved means that there will be an increase in the weight of the planes, the rate of fuel consumption for the planes will also be increased, and severl of the aircraft companies are resisting this new requirement.

At the present time, out of all the long distance cargo transport planes operated by civilian airlines, 124 planes can now be used by the government during times of emergency on the basis of the new agreement. There are 242 other passenger planes which have been designated as being available to the government as part of the reserve air fleet; these planes include 73 Boeing 707s, 104 Boeing 747s, 9 DC-8s, 50 DC-10s and 6 L-1011s. The government plan is to change over 43 more passenger planes by 1985.

Besides this, the U. S. Defense Department has also indicated a hope that several civilian aircraft companies in Europe will make planes available for the changeover as well in order to strengthen the military airlift capability of the various countries in NATO.

Israel decides to independently test produce a new generation of fighter aircraft

Israel has already rejected the idea of producing U. S. fighter aircraft in cooperation with the U. S. (that is, modified versions of the F/A-18, F-18L or F-16) and has decided to independently test produce a new generation of fighter aircraft. Because of this, Israel aircraft companies have come out with two different plans for entirely new aircraft. One plan is relatively cheap and it could be in mass production by the end of the 1980's. The other plan is relatively complicated; however, technologically speaking,

it is relatively more advanced. The Ministry of Defense selected the first design. This type of new generation fighter is called the "lion"; it has one engine and in design, it is similar to the "young lion"; however, its dimensions are relatively smaller, and its principal use is in attack role against ground targets. It is said that the air-to-air combat capabilities of this new plane will be similar to those of the F-16. Its air-to-ground capabilities will be better than those of the "young lion". It is estimated that this plane will be available to units by 1988.

Israel has proposed to the U. S. that it purchase and participate in the construction of the F404 engine which will be the power plant for the new model of fighter plane. The U. S. government has already expressed its agreement with this idea.

Canada chooses the F-18A fighter plane. The Minister of Defense of Canada has announced that Canada has selected the F-18A (the Canadian designation is CF-18) to be its next generation of fighter aircraft, replacing the present 260 aircraft in use. These aircraft in current service include CF-101, CF-104 and CF-5 types. These planes are being replaced since these three types of plane have been obsolete for 20 years.

According to the Minister of Defense of Canada, the CF-18 can satisfy the various types of military requirements of Canada better than the F-16. This fact was the principal basis for the choice which was made. From the point of view of safety, it was thought that the two-engine CF-18 is better than the one-engine F-16. Besides this, Canada also believes that the internal systems of the CF-18 are better than those of the F-16, generally speaking.

It is said that Canada will begin taking delivery of the CF-18 in the last half of 1982 and will receive two planes a month until 1989.

The British test the U. S. test produced AV-8B aircraft.

Great Britain has sent its Royal Air Force pilots as well as some of the test pilots who were responsible for the testing of the "Harrier" type of aircraft by the British aviation and space industry to the U. S. These pilots were sent to run tests on the prototype of the YAV-8B. This project was begun because of the loss of one YAV-8B last year. At the present time, the work is still continuing. It is expected that the whole job will be finished by the middle of next year. After that time, the Royal Air Force will decide whether to test produce the large-winged "Harrier" MK5 or to combine the efforts of the McDonnell-Douglas Company and the British aviation and space industry in the cooperative production of the AV-8B as a replacement for the "Harrier" GR3 which is presently in use by the Royal Air Force. The British are faced with a choice. They must decide to go ahead with their production of the "Harrier" MK5 and so maintain their leading position in the design of V/STOL aircraft, or to participate in the AV-8B plan and throw away their leading position.

In order to satisfy the requirements of the Royal Air Force, the wings of the AV-8B must be redesigned in order to be similar to the wings of the "Harrier" MK5; this is necessary in order to increase maneuvering lift. As far as cost is concerned, these two types of aircraft are very similar. The number of "Harrier" MK5 aircraft that the Royal Air Force is interested in buying is approximately 60-100 planes. The number of AV-8B aircraft that the U. S. Marine Corps is interested in buying is approximately 350 planes.

<u>Brazil test produces a turboprop training plane</u>. Brazil is currently in the midst of the test production of the EMB-312 training plane for its air force (the military designation of this plane is T-27). The idea behind the plane is this: Develop a type of military training plane which is new in concept and can be used for initial and sophisticated military flight training. Employ a turboprop engine in order to capitalize on its good characteristics (that is to say, when compared to piston engines).

This means make use of the fact that the turboprop engine lessens the amount of fuel consumed and makes it easier for student pilots to make the adjustment to jet aircraft later. Design this new training aircraft so that it satisfies the many requirements of various flight curricula and, therefore, can take the place of various types of training aircraft. This will mean savings in the area of ground maintenance, both in personnel and supplies. The adoption of a turboprop trainer will also shorten the amount of time needed for the transition to jet aircraft. Also, give the new trainer armament systems equipment to make it easier to carry out training in firing and combat maneuvers. Moreover, make the aircraft capable of taking off from non-standard types of runways; however, make it require only a minimum of maintenance and make its purchase cost and operating expenses as low as possible.

This new type of aircraft has the following types of internal safety equipment: stall speed warning device, overload warning device, a system to prevent assymetrical wing flap trims, a system to prevent the retracting of the landing gear on the ground, a system to prevent the firing of weapons systems on the ground, a system for the emergency ejection of weapons, if required, and other similar types of equipment.

The EMB-312 will be used to take the place of the T-37C which is currently in use. The takeoff distance of this aircraft is 290 m; its landing distance is 240 m; its maximum speed in level flight is 457 k/hour; its rate of climb is 10.8 m/sec; its service ceiling is 9,936 m; and, its maximum cruising range is 2,112 km. The date for the first test flight of the EMB-312 has been set for the 19th of August, this year.

<u>The Lockheed Company is doing research into the completely electrical airplane</u>

The Lockheed Company is currently in the midst of researching

the question of whether or not medium size transport planes are capable of operating with electrical systems replacing the currently used hydraulic and pneumatic systems on these planes. This company estimates that the manufacture-use-and-maintenance of this type of "all electric" aircraft will be much less costly than the same categories of expense for ordinary aircraft.

This new type of aircraft will make use of permanently magnetized generators, thinly coated with metal and electric motors to open and close the fuselage doors, extend and retract the landing gear, control cabin pressure and control the track of the aircraft. This sort of "full electrification" can also reduce the danger in case of fire because it eliminates the need for hydraulic fluid which can leak easily, get hot and catch fire.

The current situation in the research into the concept of the forward-moving rotor blade

Concerning the research into the concept of the forward-moving rotor blade by the Sikorsky Company, that is to say, the research into the concept of the ABC rotor helicopter, in level flight, this type of helicopter achieved a speed of 420 km/hr on the 6th of February, this year. This is the highest speed yet reached by a non-fixed, rotary wing aircraft.

The plane for research into the ABC rotor was to initially be carried out by the use of the Sikorsky Company's own capital. In 1972, this company received a contract from the U. S. Army for the flight testing of the ABC rotary wing. In the contract, it specified that the company would later also produce two test versions of the aircraft (the military designation for these is XH-59A). At the present time, capital for this research plan has already come from the Army, the Navy, the Air Force, NASA and the Sikorsky Company itself. Representatives from all these various agencies got together and checked over this research plan in January of this year; moreover, on the basis of test results which are already back,

these agencies signed an agreement for a 14-month continuation of this research plan. According to this plan, the Sikorsky Company will make tests flight out to a speed envelope curve of 555 km/hr. Concerning the wind tunnel testing of full-scale models of the rotors involved, this has already been carried out on the 29th of February at a NASA research center in order to speed up the test program.

Assuming normal flight patterns for helicopters, the ABC rotor helicopter, with a PT6T-3 engine in the fuselage generating the power, is planned for a speed of 315 km/hr. If one assumes complicated helicopter flight patterns, and the J60 turbojet engine is added to supply auxilliary forward thrust, then the flight speed planned for will be 555 km/hr (this assumes loading conditions of 2g).

France is in the process of test producing the M53-P2 engine. The French government-run company for the research testing and manufacture of aircraft engines is currently in the process of test producing the M53-P2 engine which is going to replace the M53-5 engine which is currently used in the French "Mirage 2000". This new type of engine is going to possess improved low pressure compressors and much better turbine cooling systems. Due to this series of improvements, the basic thrust of the engine can be expected to rise from 5.5 tons to 6.5 tons and the augmented or afterburner thrust can be expected to go from 9 tons to 10 tons. Besides this, the weight of the M53-P2 is estimated to be less than that of the M53-5 by approximately 23 kg.

The U. S. is test producing a cruise missile fired from a fighter plane. The U. S. Department of Defense has announced plans to test produce cruise missiles to be used tactically by fighter aircraft; the General Dynamics Company will be required to come up with a plan for full-scale test production.

The type of missile being discussed is a medium range air-to-ground missile (MRASM). It will be a type of "Tomahawk" missile with a 300 mile range and a conventional warhead (the range of the regular "Tomahawk missile is 1500 miles). It is planned to fire the missile from such aircraft as the A-6E, F/A-18, P-3, F-16 and F-111. The missile will be used to destroy an important target which is hardened and defended. As far as this type of missile is concerned, due to the fact that its range is longer than that of the GBU-15 air-to-ground missile which is currently in use, it is expected that the new missile will be able to reduce the opportunities for bringing down the carrying plane.

This MRASM will be produced in two types; one type is the Tercome model which will be available for use in December of 1983 and is only capable of attacking fixed targets; the other type will be available at the end of 1984, employes infrared tracking and is capable of attacking fixed or moving land or sea targets both in the daytime and at night.

At present, it is still not clear whether this missile will be produced in one copy or several; however, the cost of each copy is estimated to be approxiamtely 500,000 U. S. dollars. MRASM is a designation given to this type of missile by the Department of Defense, but the General Dynamics Company calls it TALCM (an air launched tactical cruise missile).

<u>A new form of single element airborne surveillance and tracking radar</u>. The RCA Company, on the basis of its Primus weather radar, is in the process of test producing a type of military single element airborne search and tracking radar (MASTR). This type of radar will improve the capability of military helicopters and fixed wing aircraft to search out and track targets in all conditions of visibility and weather. It is capable of rejecting complex reflected signals from the surface of the sea while it is still able to estimate the track of the aircraft in order to facilitate the control and firing of weapons.

The possible uses of MASTR are as follows: In the guidance of subsonic ground-to-ground missiles, in helicopter search for targets above the horizon, in the guidance of all-weather remote control flying apparatuses, in the air-to-ground search for targets, in the air defense, fire control and battlefield reconnaissance of bases and their environs, as well as in other similar applications.

This type of x wave band radar weighs 70 pounds and has external case dimensions of 38 inches (length) and 15 inches (diameter). A planar slot antenna is driven directly by electric motors along two axes. Double wave path single pulse wave bundles are controlled by the microprocessor. This sort of radar is also capable of tracking interference sources as well as operating in a single wave path mode.

This type of radar has automatic test equipment as well as circuits to fight interference; it is capable of putting out a multi-colored numerical display. This new type of radar is also fitted with solid state transceivers and equipment for the control of complex echos. The flight testing of the system is scheduled for September of this year.

A British company test produces an electronic combat simulator. A British company will soon finish the work of test producing an electronic combat simulator which was contracted for by the British Ministry of Defence. This simulator will be used by the Royal Air Force as a research tool in the weapons section of its research institute in order to promote the development of new electronic countermeasures.

This simulator includes 40 components, two computers and five microprocessors, and is capable of simulating the flight of an aircraft when it is in the operational range of any selected type of fire control radar. It simulates the entire engagement process for

the whole radar and weapons system. It can also be used to determine the effects of a sudden missile attack and to figure out the actual miss distance. All simulators are real time.

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